Science and the Return to the Moon:
The Vision for Space Exploration

Paul D. Spudis
Lunar and Planetary Institute

spudis@lpi.usra.edu

www.spudislunarresources.com

NLSI Lunar Science Conference
NASA Ames Research Center
Mountain View, CA
21 July, 2008

What's the value of exploration?

Humans explore because it conveys an evolutionary advantage

- exploration broadens experience and imagination, permitting better prediction of the future, ensuring better odds for survival
- curiosity and its satisfaction is intellectually and emotionally satisfying

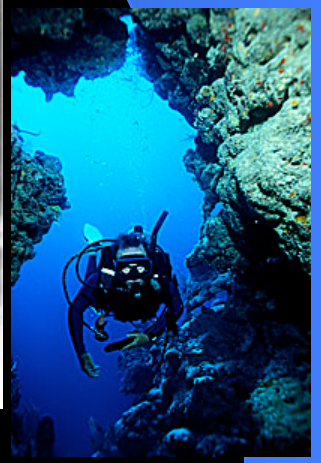
Exploration improves our ability to solve problems

- increased imagination and knowledge base permits recognition of innovative approaches and solutions
- helps focus energies on posing the right questions, or, on questions that *can* be addressed and answered

Exploration excites and inspires the creative, productive segments of society

- permits intellectual connections and relations that might not otherwise occur (the 'ah-ha!' syndrome)
- Frontiers are unknown, mysterious places that stimulate imagination

H.M.S. Challenger preparing to Sound, 1872.



Exploration ≠ Science

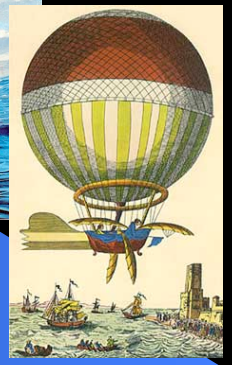
Exploration **is going into the unknown, probing the frontier, looking over the next hill.**

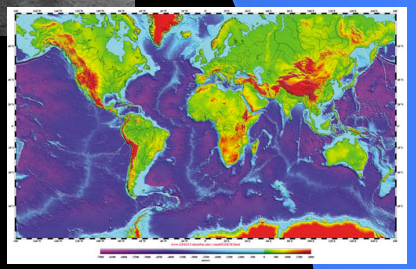
- It has structure, but is not directed
- Discoveries sometimes build on each other, sometimes are isolated

Science **is the process by which we explain nature**

- It has a well-defined, directed structure (observation, hypothesis, experiment, verification)
- Scientific knowledge is cumulative and self-correcting

Both are dynamic, not static. Science always follows exploration





Exploration precedes and enables science

Exploration and Science

"Exploration without science is tourism" – A NASA official

Exploration is *broader and richer* than science

- Security and asset protection
- Wealth creation
- Settlement and infrastructure development

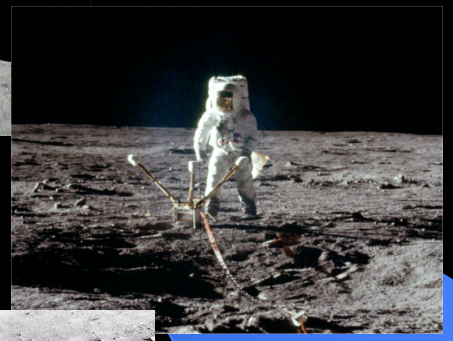
Exploration *enables* science

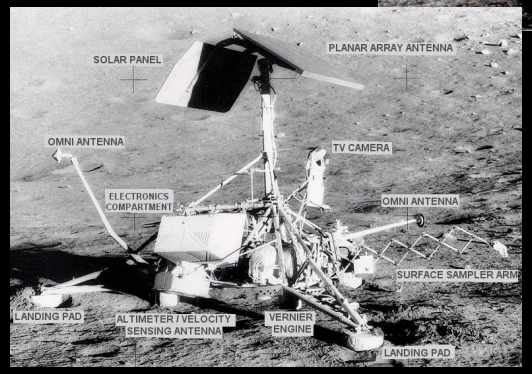
- Access to remote locales and exotic environments
- Exploratory infrastructure permits scientific investigation

Why Human Spaceflight?

The rational dimension

- **People bring unique capabilities to space exploration**
  - Conduct field science, requiring intense interaction of human with environment
  - Repair and maintain complex equipment and installations
- **Machines do not and will not possess intelligence of necessary magnitude to explore the solar system**
  - Robots are good for remote, hostile environments to provide first-order reconnaissance
  - Robots can be designed to answer focused questions (hypothesis testing) or make precision measurements





But: **We don't always know ahead of time what measurements are significant and which are irrelevant**

Why Human Spaceflight?

The emotional dimension

Inspiration

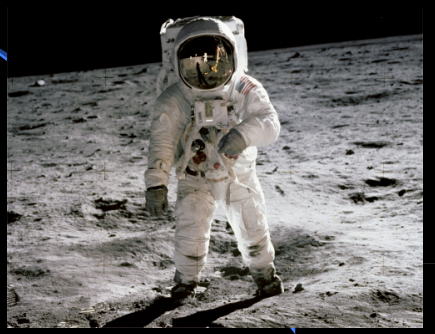
- People in space are our surrogates; vicarious exploration
- Cathedral building; scale is too big for one generation
- A human window onto the universe

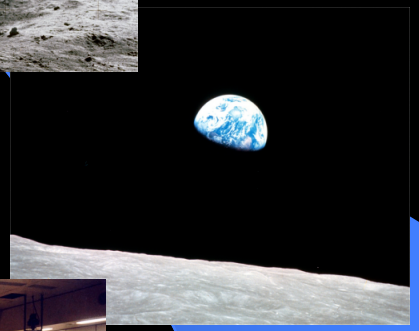
Drama

- Marked upsurge of public interest during crises (e.g., Apollo 13)
- Emotion and curiosity (about past and future)
- A modern gladiatorial contest, without the gore

Spectacle

- Invokes our pioneer/frontier origins
- Encourages a communal perspective
- Belief in the future; something bigger than ourselves

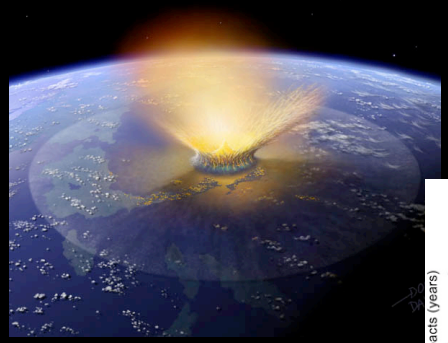


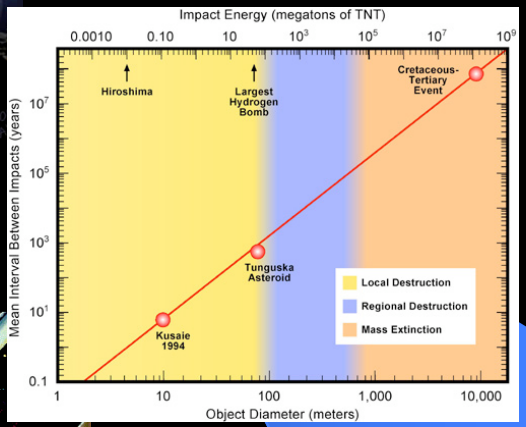


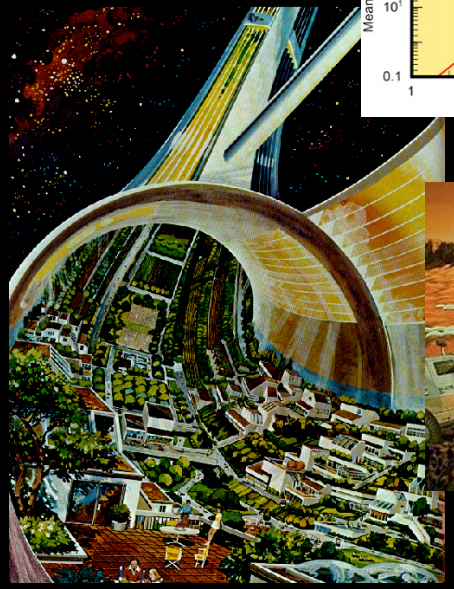
Human Spaceflight

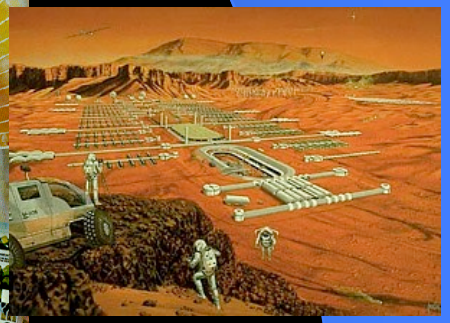
The Ultimate Rationale

- Study of Apollo samples taught us key signs of large-body impact
- We have since found that large objects collide with Earth on a quasi-regular basis
- Not a question of *if*, but *when*
- Conclusion: **We're doomed**
- Solution: Multiple reservoirs of human culture









Why the Moon?

It's close

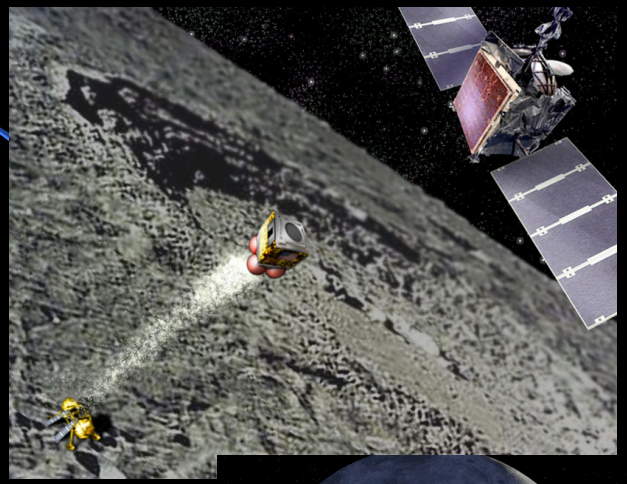
- Three days away and easily accessible (as near as GEO)
- Transport system to Moon can also access GEO, cislunar, Earth-Sun Lagrangians, and some asteroids

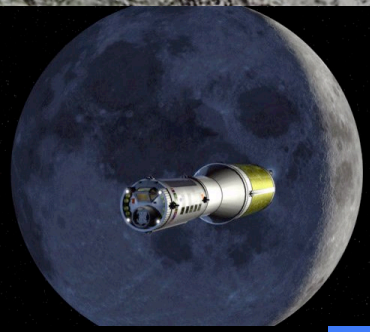
It's interesting

- Moon contains a record of planetary history, evolution and processes unavailable for study on Earth or elsewhere

It's useful

- Retire risk to future planetary missions by re-acquiring experience and testing with lunar missions
- Development of lunar resources has potential to be a major advancement in space logistics capability





The Vision for Space Exploration

- Conceived in response to loss of Columbia Space Shuttle, Feb. 1 2003
- Five steps:
  - Return Shuttle to flight
  - Complete ISS assembly and retire Shuttle
  - Build new human spacecraft (CEV) for transport beyond LEO
  - Return to the Moon with people and robots to explore and prepare for voyages beyond
  - Human missions to Mars and other destinations
- Proposed by President Bush, endorsed by 109th Congress
  - VSE is now national policy

Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress – one mission, one voyage, one landing at a time.

President George W. Bush - January 14, 2004

S. 1281

One Hundred Ninth Congress
of the
United States of America

AT THE FIRST SESSION

Begun and held at the City of Washington on Tuesday, the fourth day of January, two thousand and five

An Act

To authorize the programs of the National Aeronautics and Space Administration.

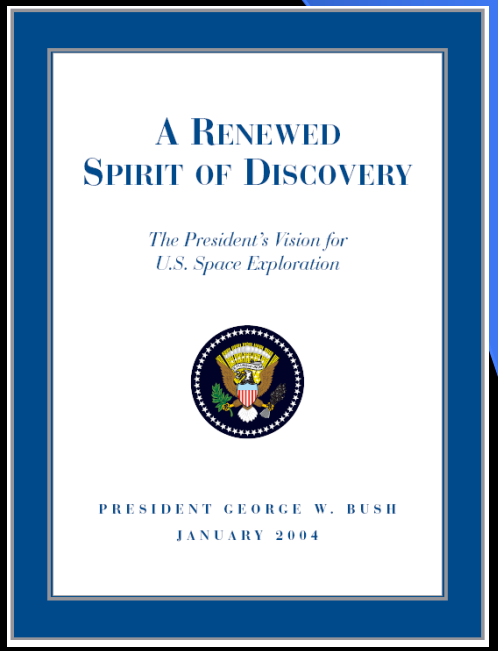
Founding VSE Policy Documents

Vision for Space Exploration speech

- Intent is to create both an extended human presence in space and a sustained program.
- The Moon plays a key role:
  - Our first destination beyond LEO
  - Serves as a test bed for development of systems, procedures and techniques and a staging area for missions beyond
  - Use of lunar resources is specifically mentioned

***Renewed Spirit of Discovery* document**

- Three rationales for U.S. space exploration: science, security, and economy
- Goal is a sustained and affordable program
- Use the Moon to create new capability; learn how to live and work off-planet
- Lead with robotic missions that gather key information *and* emplace assets before the arrival of people
- Key activities of human missions to the Moon are *science* and *development of new approaches,* both with the aim of creating a *sustained* program
- Learning to use lunar resources is specifically identified as one of these new approaches

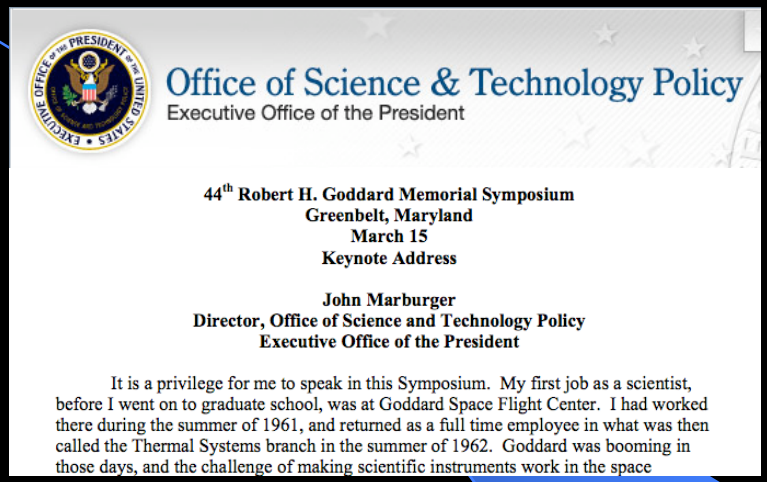


An Overlooked Key Policy Document

Speech by OSTP Director and President's Science Advisor John Marburger at Goddard Symposium, March 15, 2006

Critical Points:

- Incorporate Solar System into our economic sphere
- Ultimate goal is *to use* space for benefit of mankind
- Moon is of unique significance -- closest and most accessible source of materials and energy out of Earth's gravity well
- Development of off-planet resources makes entire Solar System accessible
- Critical architectural consideration: Space exploration budget must grow at low level to be sustainable



Office of Science & Technology Policy
Executive Office of the President

44th Robert H. Goddard Memorial Symposium
Greenbelt, Maryland
March 15
Keynote Address

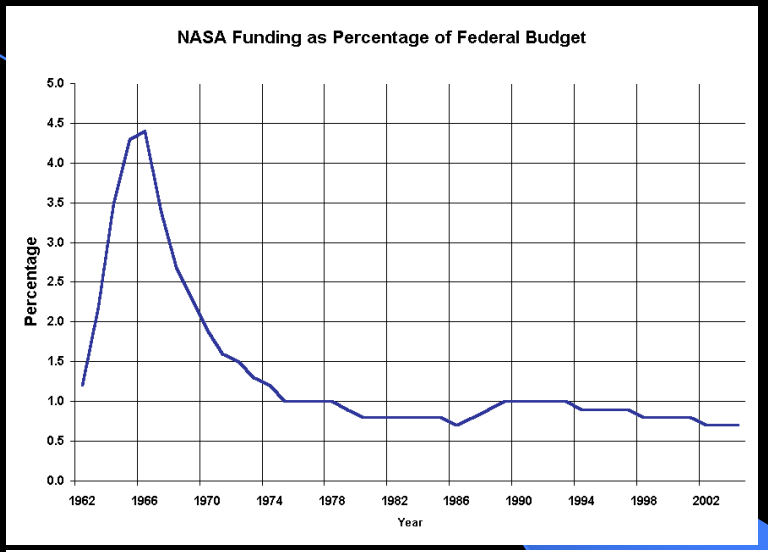
John Marburger
Director, Office of Science and Technology Policy
Executive Office of the President

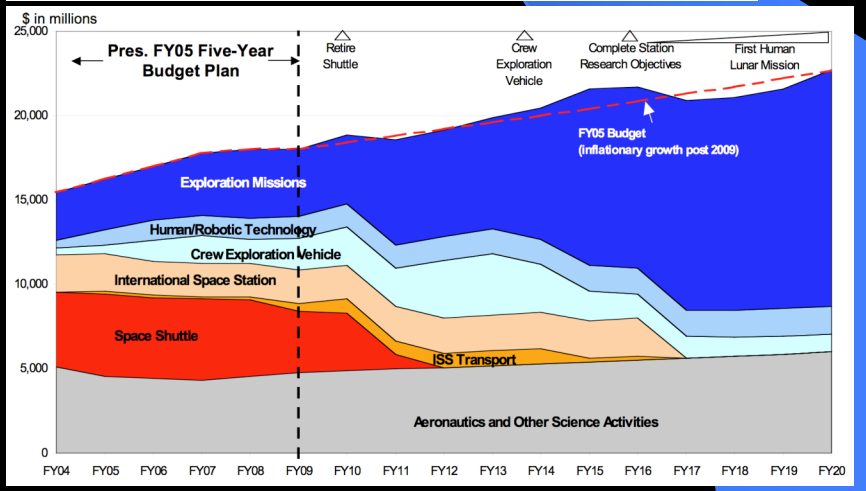
It is a privilege for me to speak in this Symposium. My first job as a scientist, before I went on to graduate school, was at Goddard Space Flight Center. I had worked there during the summer of 1961, and returned as a full time employee in what was then called the Thermal Systems branch in the summer of 1962. Goddard was booming in those days, and the challenge of making scientific instruments work in the space

http://www.ostp.gov/pdf/jhmgoddardsymp03_15_06release.pdf

The Vision: A Fundamental Premise

- Apollo was a politically driven program; we are NOT in a similar situation
- Congress has funded NASA at (more or less) a constant level for the last 30 years (~ 1% of federal budget)
- Such spending levels appear to be politically "sustainable"
- We must be clever enough to architect a lunar return that fits this budget profile. How?
  - Small, incremental, cumulative steps
  - Learn to use what we find in space to create capability
  - Extend human reach in stages





Free variables: Apollo = funding; VSE = schedule

Deriving the VSE lunar "mission"

Common themes from the VSE policy documents:

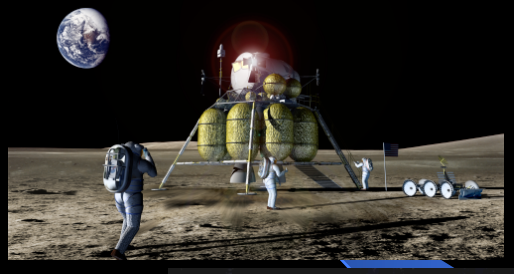
- Sustainable and affordable program
- Explore with robots *and* humans
- Test bed for systems and procedures on the Moon
- Lunar resource utilization
- Creation of new space flight capability

We are going to the Moon to learn the skills we need to live and work productively off-planet

What are these skills?

Arrive

- Create transportation system to take humans to and from the Moon
- Use this system to access cislunar and translunar space

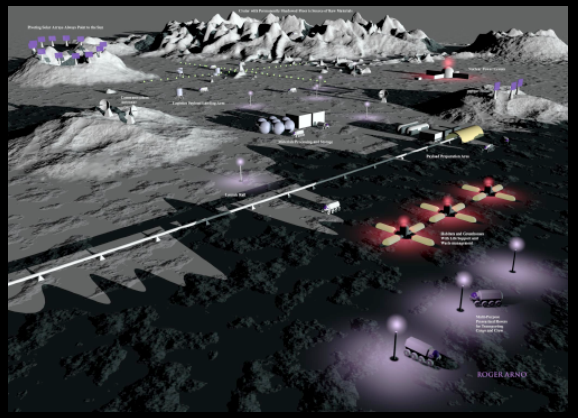


Survive

- Build habitat to safely house human explorers
- Protect from environmental hazards
- Extract consumables from local materials

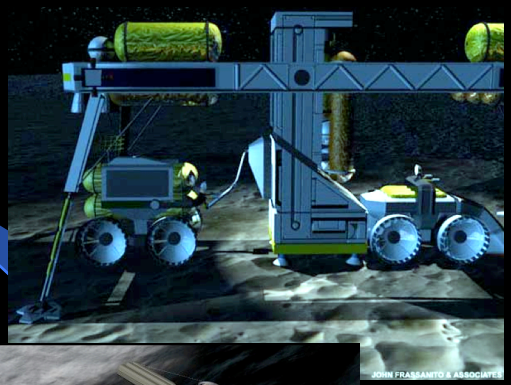
Thrive

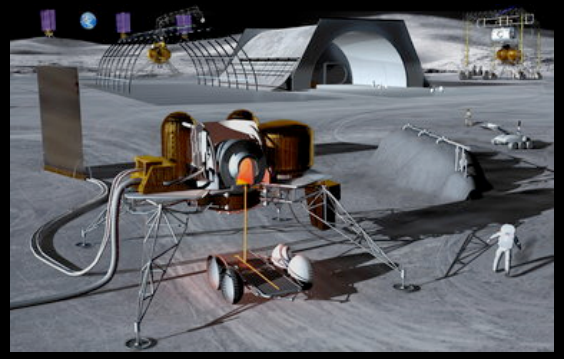
- Create new infrastructure and capabilities by using the material and energy resources of the Moon
- Extend this economic zone first to cislunar, then to translunar space



Architectural Implications

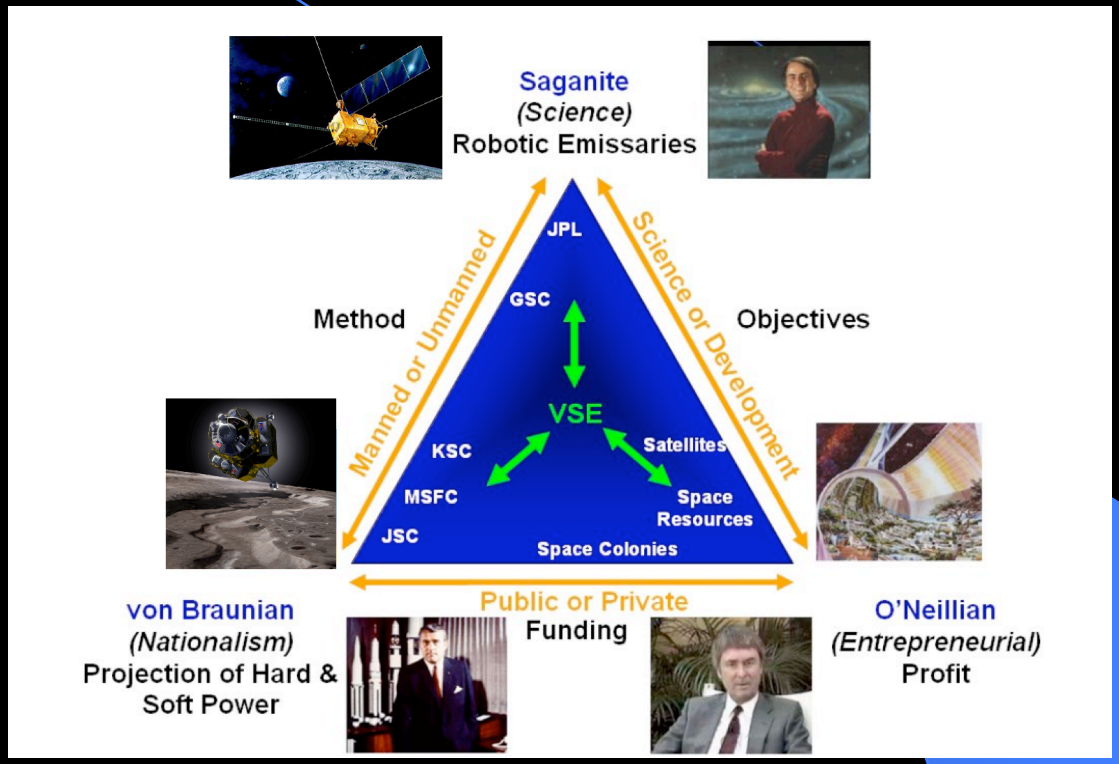
- Use robotic flights to acquire strategic knowledge *and* emplace assets
  - robotic missions are *not* just for science
- Commonality of hardware, systems, procedures between robotic and human flight elements
  - test Altair components on robotic missions
- Locate "high grade" lunar resources and build human habitats nearby
  - concentrated resources (e.g., polar ice) are easiest to use; focus on them first
- Build up infrastructure in a single location to create capability rapidly
  - Forget sorties: pick the site and build up an outpost





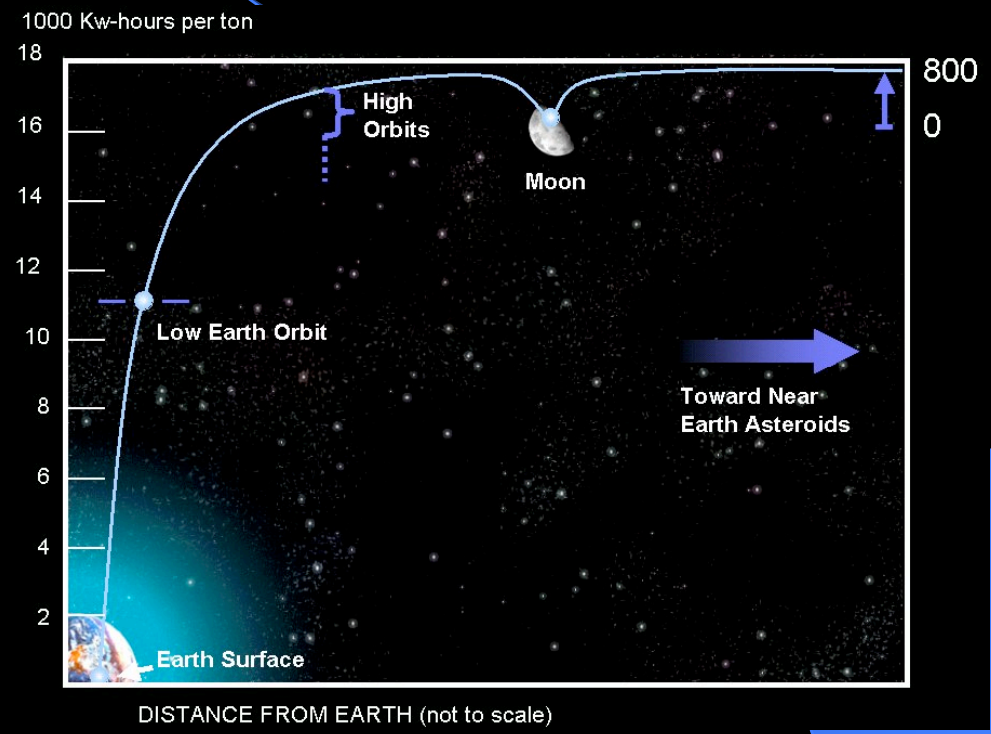
Science and the Vision I

- Science is a key part of the Vision
- Pure science v. Applied science
  - Scientific exploration will always be a part of the NASA portfolio
  - Applied sciences at core of making space "useful"
  - The Vision makes applied science an important, co-equal part of the space program



Science and the Vision II

- If we are successful in using space resources, new scientific opportunities will arise
- Conversely, future scientific opportunities will be limited if we must always bring what we need in space from Earth



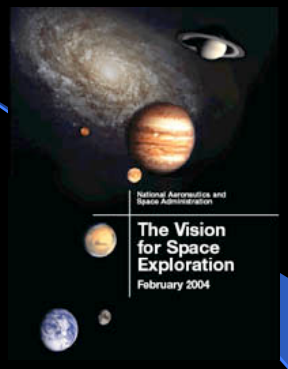
The Vision for Space Exploration

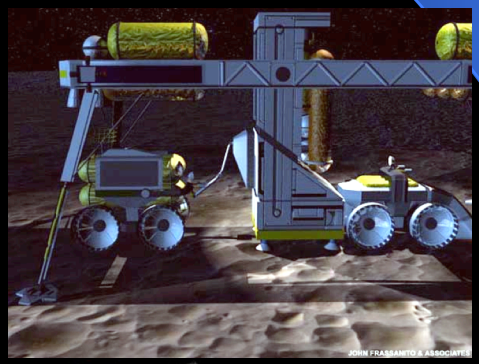
What is the VSE?

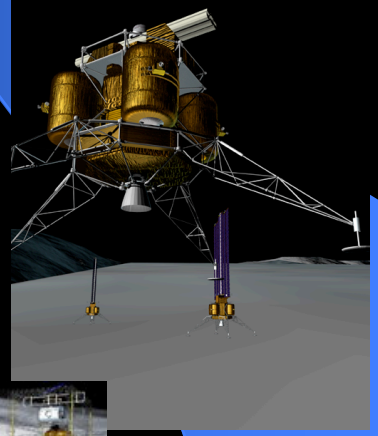
- A strategic direction
- Small, incremental, cumulative steps
- Create new space-faring capability
- Can humans thrive off-planet?

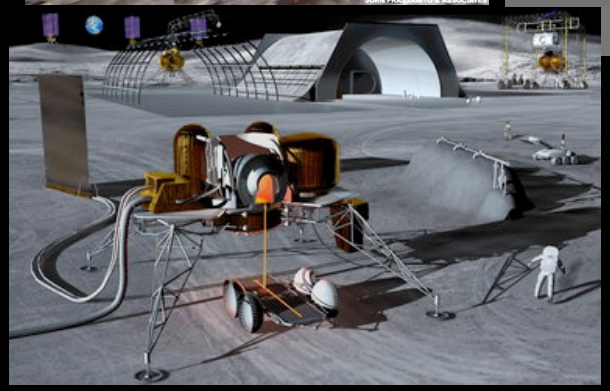
What isn't the VSE?

- A science entitlement
- A rocket-building entitlement
- Apollo to Mars
- The next "NASA program"

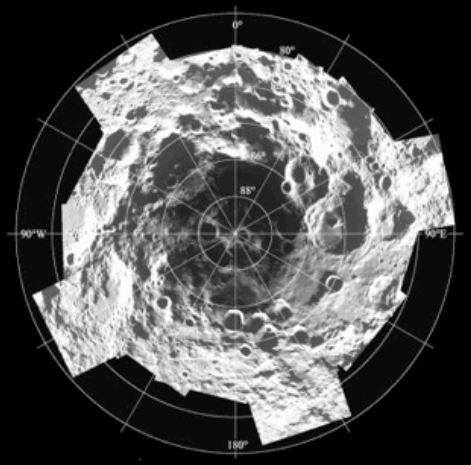








For more information, go to:
http://www.spudislunarresources.com



Spudis Lunar Resources

Using the Moon to learn how to live and work productively in space

What's this web site all about?

Paul D. Spudis, Ph.D.

spudis@lpi.usra.edu

Home Resume Bibliography Opinion/Editorial Papers Moon 101 Images/Maps Links Blog

Or e-mail me at:

spudis@lpi.usra.edu